Monitoring Forest Health Using DESIS and Sentinel-2 Data

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Study Site: Bavarian Forest National Park (BFNP)

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PERSPECTIVE

Methods in Ecology and Evolution | BRITISH ECOLOGICAL SOCIETY

A laboratory for conceiving Essential Biodiversity Variables (EBVs)—The 'Data pool initiative for the Bohemian Forest Ecosystem'

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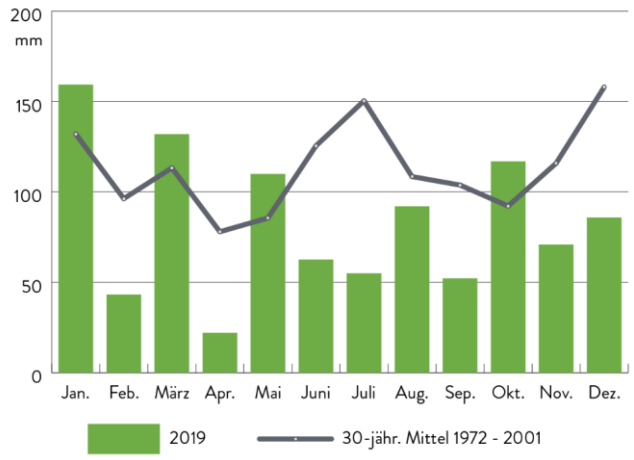
„… functioning as a pool of data and algorithms … providing test fields for feasibility studies on earth observation missions."

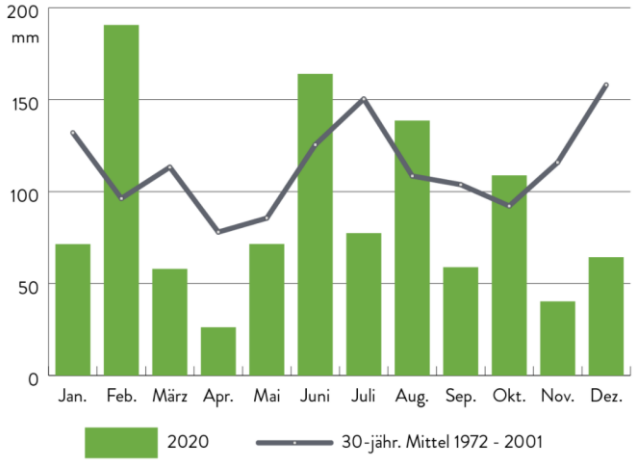
Observable Climate Changes in the BFNP

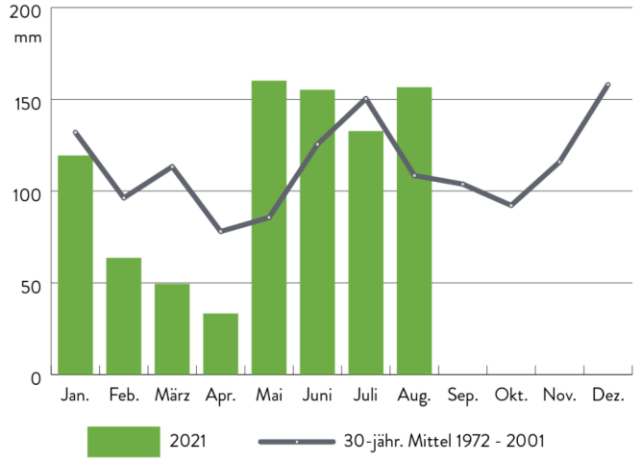
Since weather recording in the National Park (1972)…
… 2019 the third hottest year
… 350 millimeters less precipitation than average in 2019
… second lowest "number of days with snow“ in 2020
… lowest number of ice days in 2020
… 20°C mark was exceeded in March 2021 for the first time

Effects on the National Park
→ increased emergence of bark beetle
→ infestation of native spruce trees
→ beech trees still cope with climate change

Monthly precipitation in BFNP (Jan 2019 – Aug 2021)







https://www.national-park-bayerischerwald.bayern.de/aktuelles/wetterstation/index.htm

Research Questions

- Use of Sentinel-2 in combination with DESIS data to observe changes in vegetation status over time
  - ✓ Sentinel-2: temporal high resolution
  - ✓ DESIS: spectral high resolution
  - ✓ spatial resolution same order of magnitude
  - ✓ use of spectral indices to maximize sensitivity to vegetation characteristics (Hill et al., 2019)

→ examine DESIS data

→ investigate whether both datasets can be combined

→ decision on suitable spectral indices

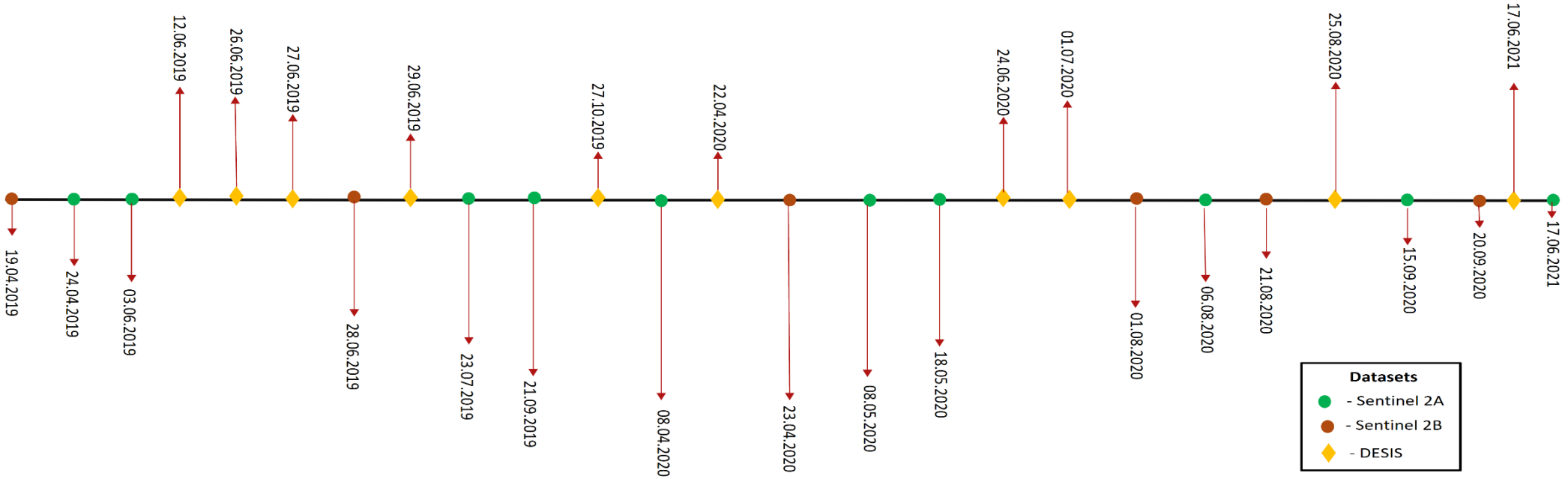
Data Base: DESIS and Sentinel-2 Cloud Free Data Acquisitions 2019 - 2021

DESIS (L2A)

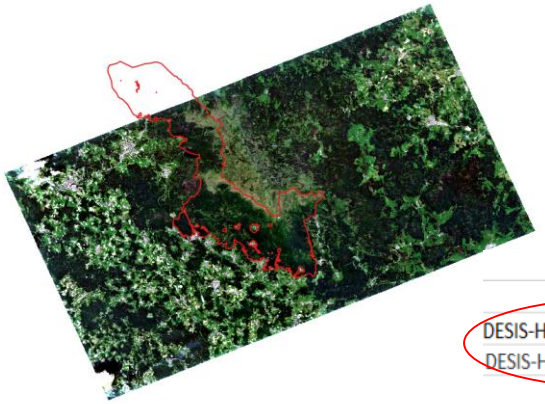
- 4 * binning with 60 spectral bands at ~10.20 nm FWHM (Alonso et al., 2019)
- Spatial resolution 30 meters
- Wavelength ranging from 430 – 975 nm (after removal of noisy bands)

Sentinel 2 (L2A)

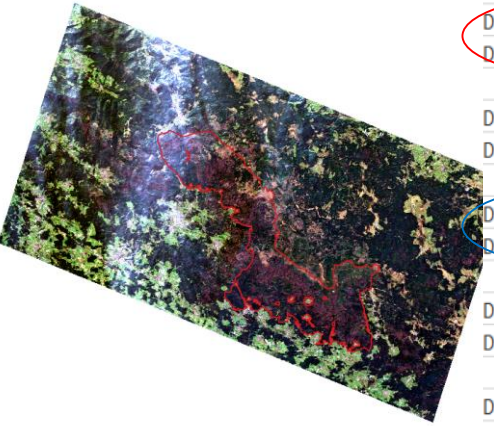
- MAJA corrected (Hagolle et al., 2017)
- 12 bands (9 spectral bands considered for analysis)
- Spatial resolution - 20 meters (for all bands, resampled)
- Wavelength ranging from 490–2185 nm (taken till 1000 nm)



DESIS Imagery

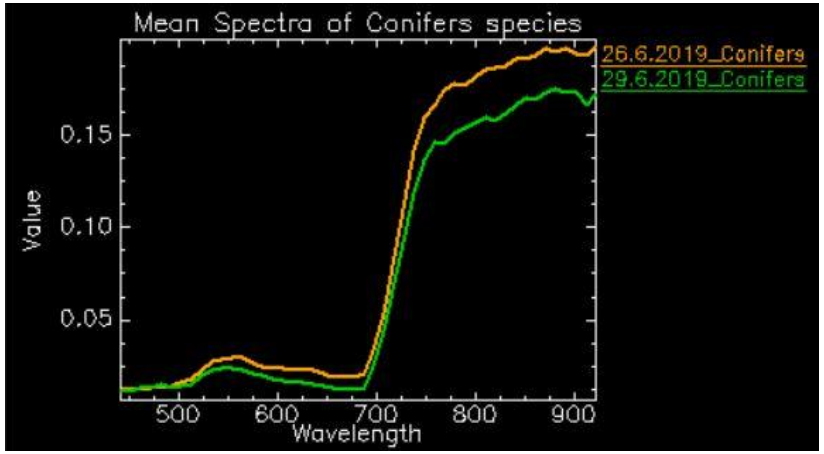


No full coverage



Hazy scene

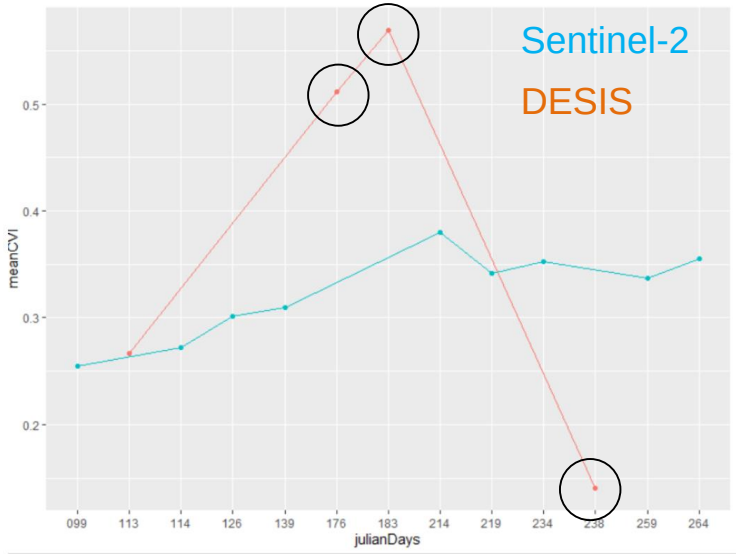
Contrails



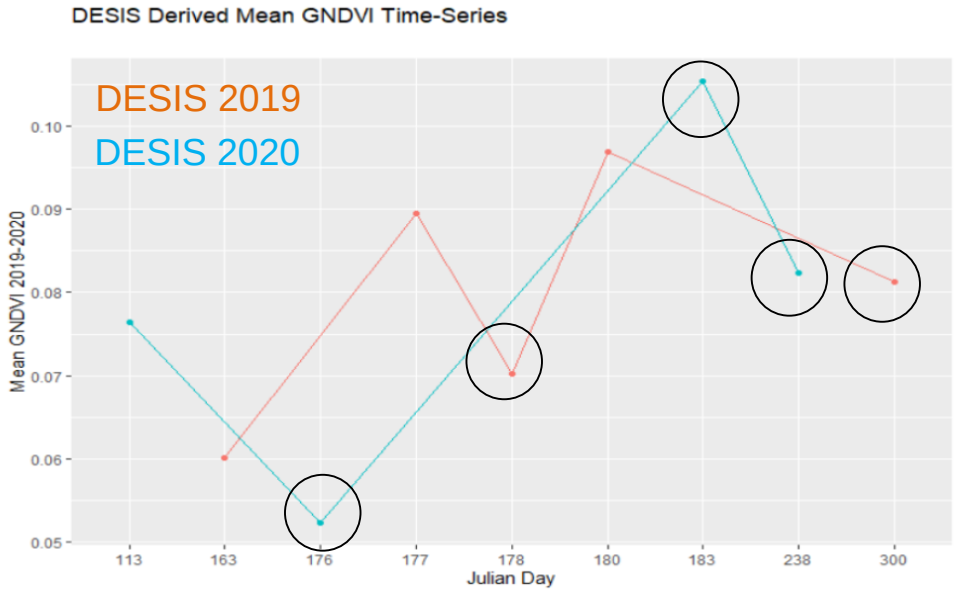
Product	Cloud Coverage Percentage	Quality Rating	Solar zenith angle	Solar azimuth angle	Acquisition Mode	Acquisition Date	Acquisition Time
DESIS-HSI-20190612T112803-004	0 to 25	Acceptable	26.09	191.26	image_strip_mode	6/12/2019	11:29:42 GMT
DESIS-HSI-20190612T112803-005	Clear	Acceptable	26.25	192	image_strip_mode	6/12/2019	11:29:47 GMT
DESIS-HSI-20190626T093518-003	0 to 25	Acceptable (Contrails present in image)	31.65	135.68	image_strip_mode	6/26/2019	09:36:53 GMT
DESIS-HSI-20190626T093518-004	0 to 25	Acceptable	31.41	136.15	image_strip_mode	6/26/2019	09:36:57 GMT
DESIS-HSI-20190627T053207-002	Clear	Acceptable	69.1	78.05	image_strip_mode	6/27/2019	05:33:36 GMT
DESIS-HSI-20190627T053207-003	Clear	Acceptable	68.84	78.35	image_strip_mode	6/27/2019	05:33:41 GMT
DESIS-HSI-20190629T084322-002	Clear	Acceptable	38.81	118.32	image_strip_mode	6/29/2019	08:44:52 GMT
DESIS-HSI-20190629T084322-003	Clear	Acceptable	38.54	118.62	image_strip_mode	6/29/2019	08:44:57 GMT
DESIS-HSI-20191027T085155-002	25 to 50	Acceptable	67.17	148.24	image_strip_mode	10/27/2019	08:53:24 GMT
DESIS-HSI-20191027T085155-003	0 to 25	Acceptable	66.96	148.6	image_strip_mode	10/27/2019	08:53:29 GMT
DESIS-HSI-20200422T103335-002	Clear	Acceptable	37.24	167.01	image_strip_mode	4/22/2020	10:35:05 GMT
DESIS-HSI-20200422T103335-003	Clear	Acceptable	37.08	167.58	image_strip_mode	4/22/2020	10:35:10 GMT
DESIS-HSI-20200624T060732-015	0 to 25	Acceptable	63.18	84.4	image_strip_mode	6/24/2020	06:09:58 GMT
DESIS-HSI-20200624T060732-016	0 to 25	Acceptable	62.92	84.72	image_strip_mode	6/24/2020	06:10:03 GMT
DESIS-HSI-20200701T070033-006	Clear	Acceptable	54.95	94.5	image_strip_mode	7/1/2020	07:02:20 GMT
DESIS-HSI-20200701T070033-007	Clear	Acceptable	54.7	94.71	image_strip_mode	7/1/2020	07:02:24 GMT
DESIS-HSI-20200825T090349-002	0 to 25	Acceptable	46.49	135.22	image_strip_mode	8/25/2020	09:05:19 GMT
DESIS-HSI-20200825T090349-003	25 to 50	Acceptable	46.24	135.61	image_strip_mode	8/25/2020	09:05:23 GMT

Choice of DESIS Imagery for Further Analysis

- Only prerequisite: cloudfree scenes



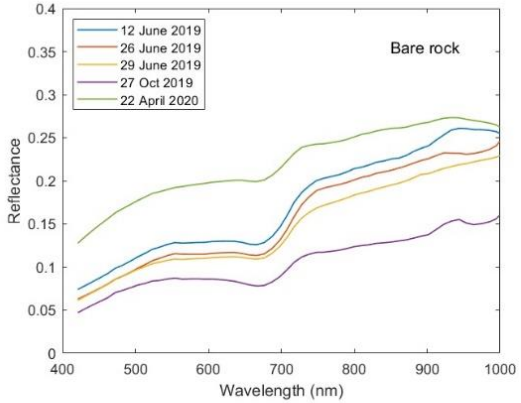
◯ SZA > 40 °

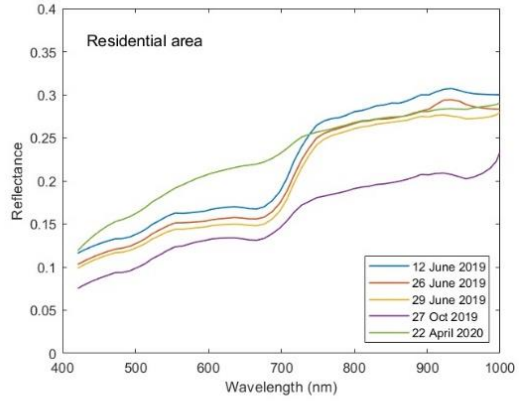


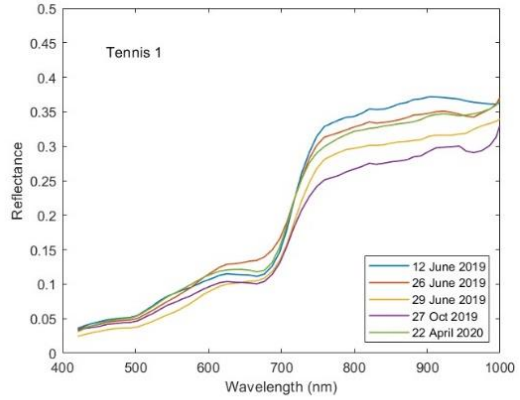
→ further selection necessary to obtain meaningful results

- solar zenith angle < 40˚

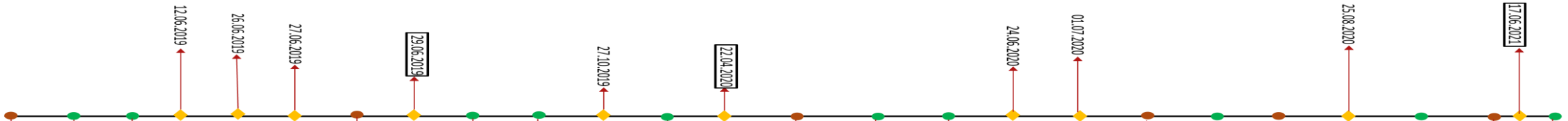
Differences in spectra of homogeneous sites







→ Result: One data set per year (3 out of 10 acquisitions)



Comparison of S-2 and DESIS

- Selection of homogeneous pseudo-invariant testing sites
- Choosing images pairs from available S-2 and DESIS data

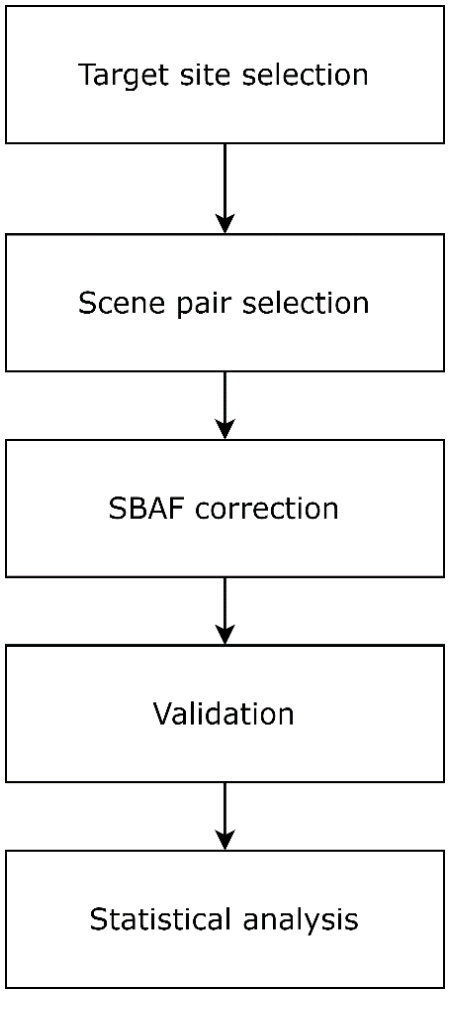
- Spectral Band Adjustment Factor → equalization of two sensors

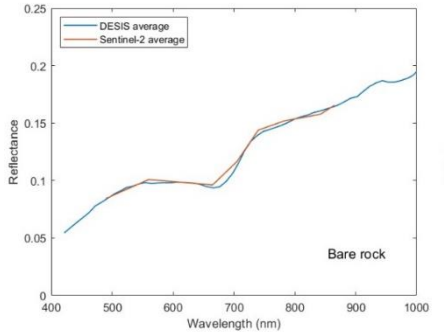
$$SBAF = \frac{\rho_{\lambda(DESIS)}}{\rho_{\lambda(S2)}}$$

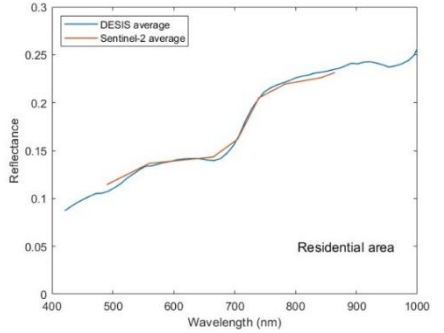
- Resample to the same spectral/spatial resolution
- Compare the eight VNIR spectral bands at 490, 560, 665, 705, 740, 783, 842, and 865 nm
- For all sites, SBAF is close to 1:1 → good agreement

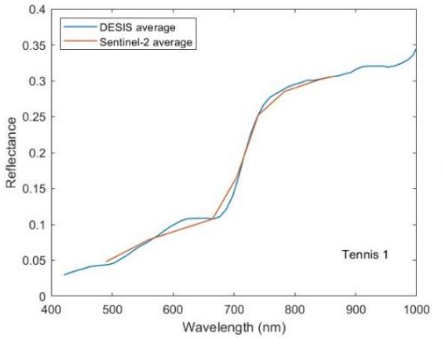
→ DESIS in-orbit spectral performance is stable and accurate compared to Sentinel-2

→ Radiometric difference is within 3% based on comparison with S-2 mission









Bands / Sites	490	560	665	705	740	783	842	865
	Blue	Green	Red	Red-edge	Red-edge	Red-edge	NIR	NIR
Bare rock	1.0072	0.9566	0.9256	1.0097	0.9981	1.0126	1.0658	1.0311
Lake	1.2265	0.6758	1.0001	1.0000	1.0000	1.0000	1.0000	1.0001
Grass	0.8889	0.9645	0.6713	1.0126	1.0249	1.0054	1.0247	1.0061

Supporting Data from the National Park

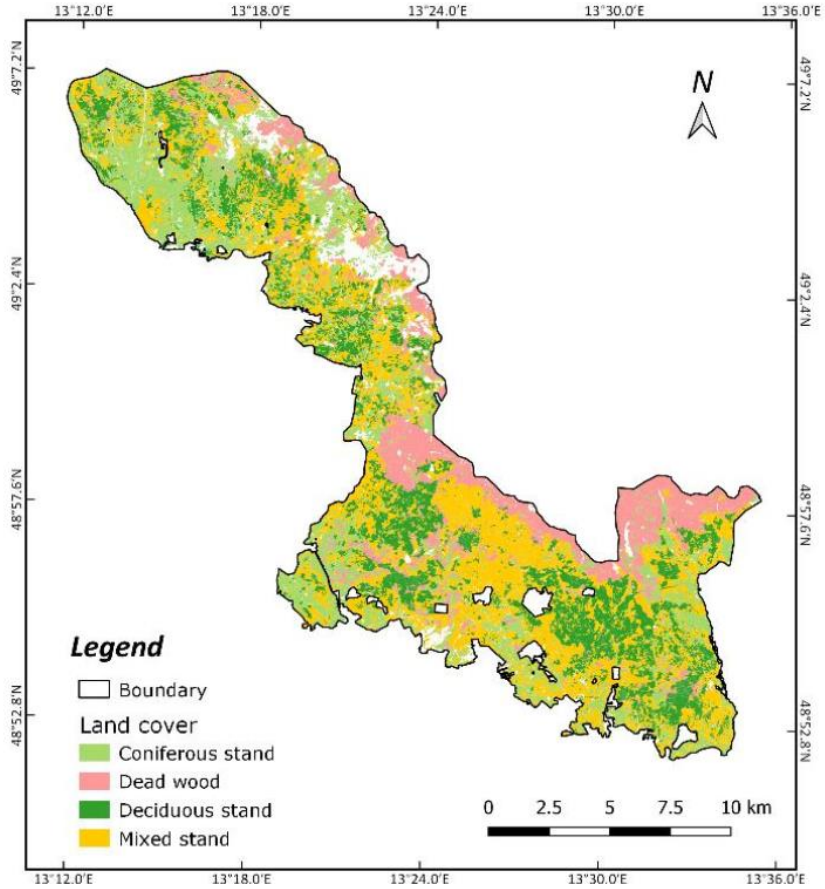
- Information on forest type
- Information on deadwood types
- Information on infestation year

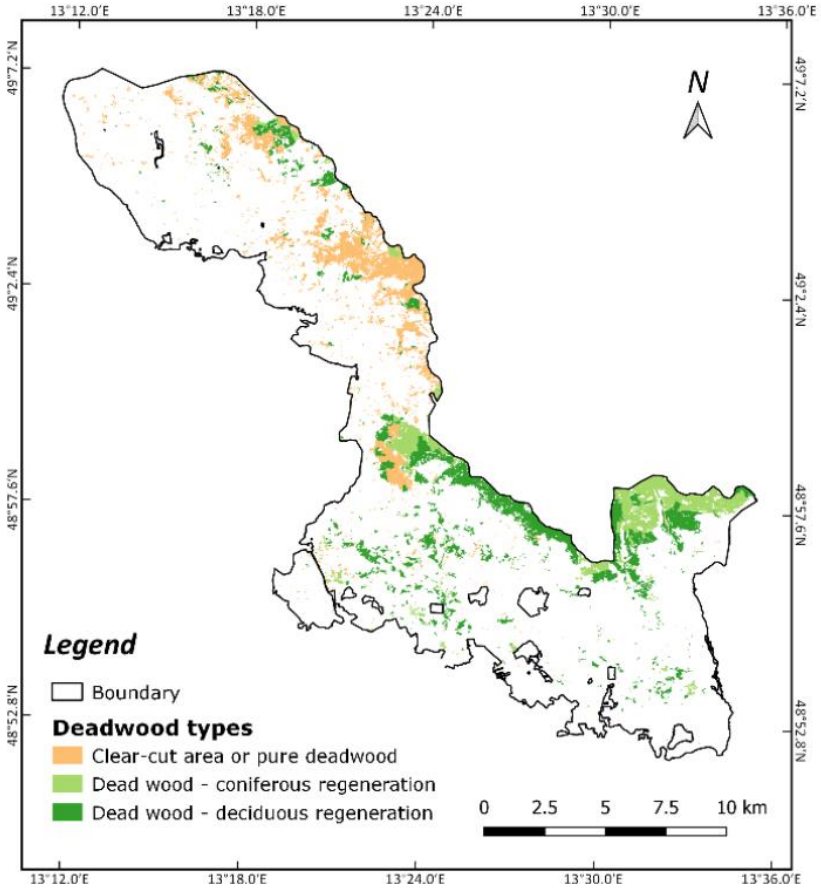
Concentrate analysis on coniferous areas

✓ Evergreen

✓ Less pronounced seasonal changes

✓ Link to bark beetle infestation





Vegetation Index Mapping

- Forests are influenced by many external factors
- Tracking change of single vegetation index is not able to reveal the impact due to confounding factors
- CVI = (NDVI + VIgreen + NDRE) / 3 (Hill et al., 2018)

Group	Vegetation index	Related information	Original Formulas
NIR – Rededge	NDRE	Chlorophyll content, greenness	$\frac{NIR - Rededge}{NIR + Rededge}$
Visible – Visible	VI_{green}	Leaf pigment, vegetation status	$\frac{Green - Red}{Green + Red}$
NIR – Visible	NDVI	Biomass, LAI	$\frac{NIR - Red}{NIR + Red}$

List of Vegetation Indices (Morcillo-Pallarés et al., 2019)

Bio-physical variables :

Structural

Normalized Difference Vegetation Index (NDVI) – **D & S2**

Green Normalized Difference Vegetation Index (GNDVI) -**D & S2**

Specific Leaf Area Vegetation Index (SLAVI) – **S2**

Chlorophyll

Normalized Difference Red Edge Index (NDRE) - **D & S2**

Chlorophyll Absorption Ratio Index (CARI) - **D**

Modified Chlorophyll Absorption Ratio Index (MCARI) - **D**

Chlorophyll Green Index (ChGreen) - **D**

Leaf pigment

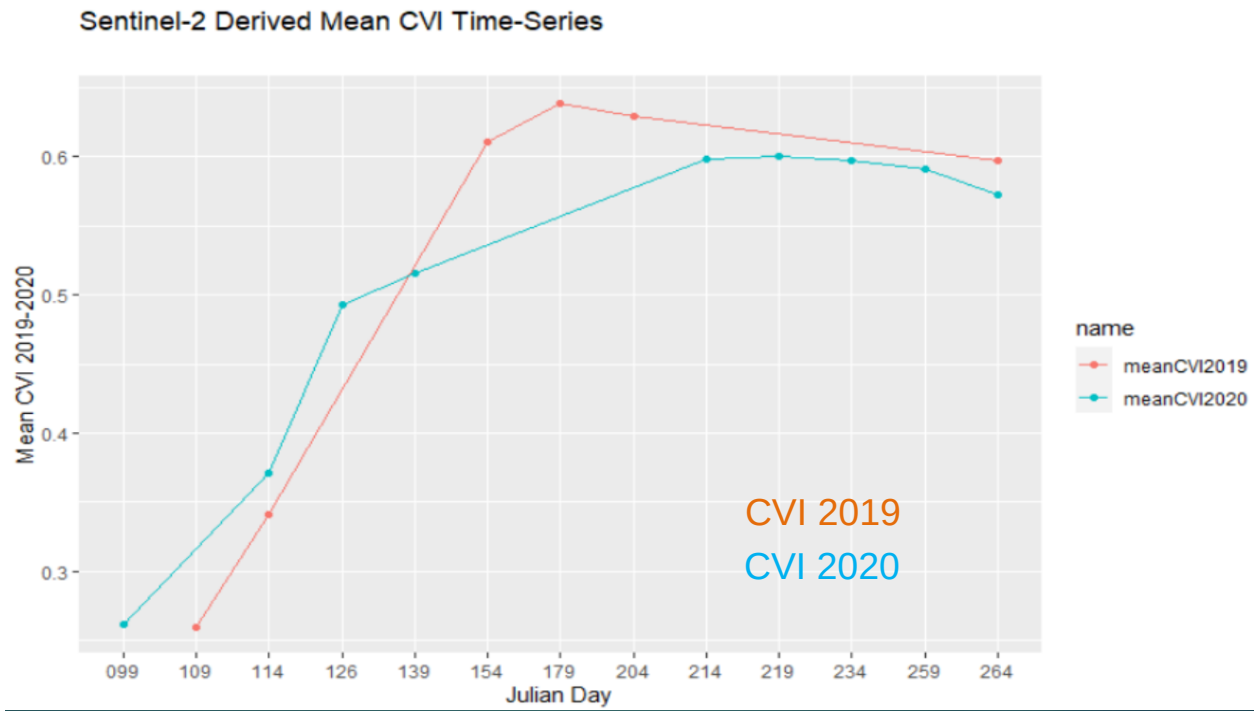
Visible Atmospherically Resistant Indices Green (VIGreen) - **D & S2**

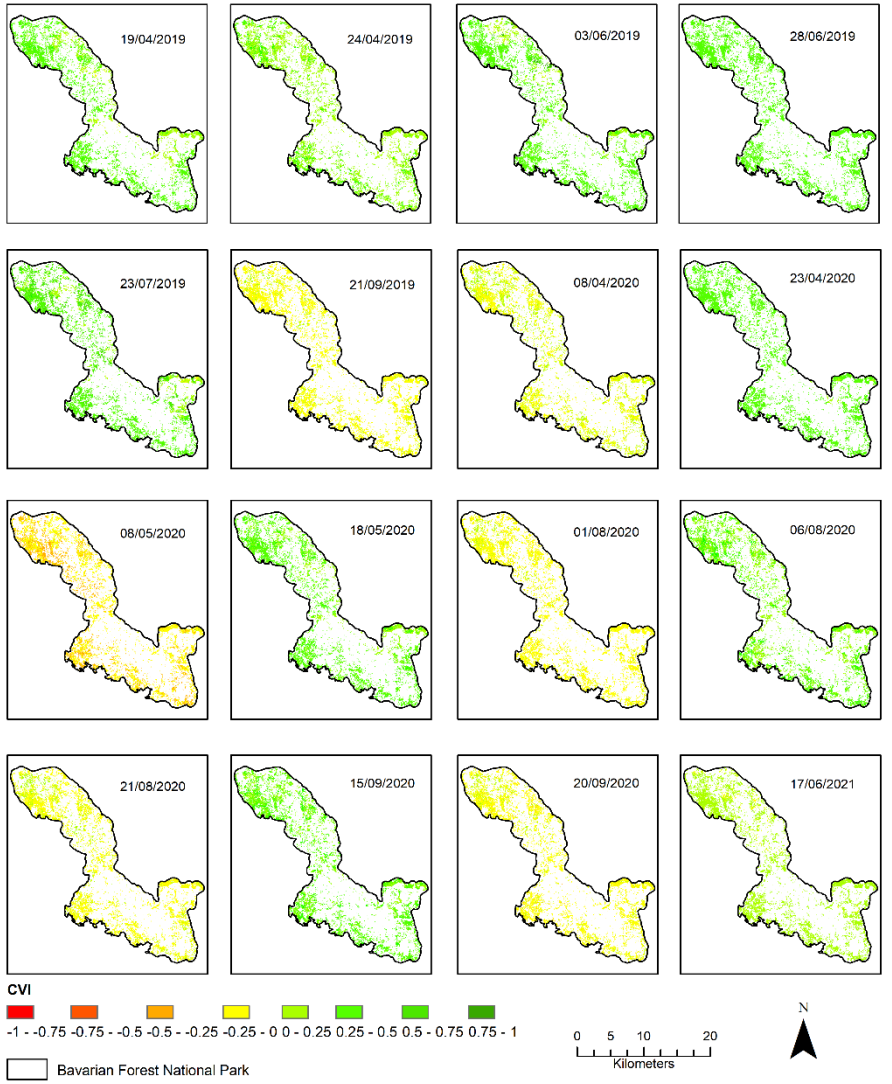
Carotenoid Reflectance Index (CRI) – **D**

Anthocyanin Reflectance Index (ARI) – **D**

Combined Vegetation Index Mapping using Sentinel - 2

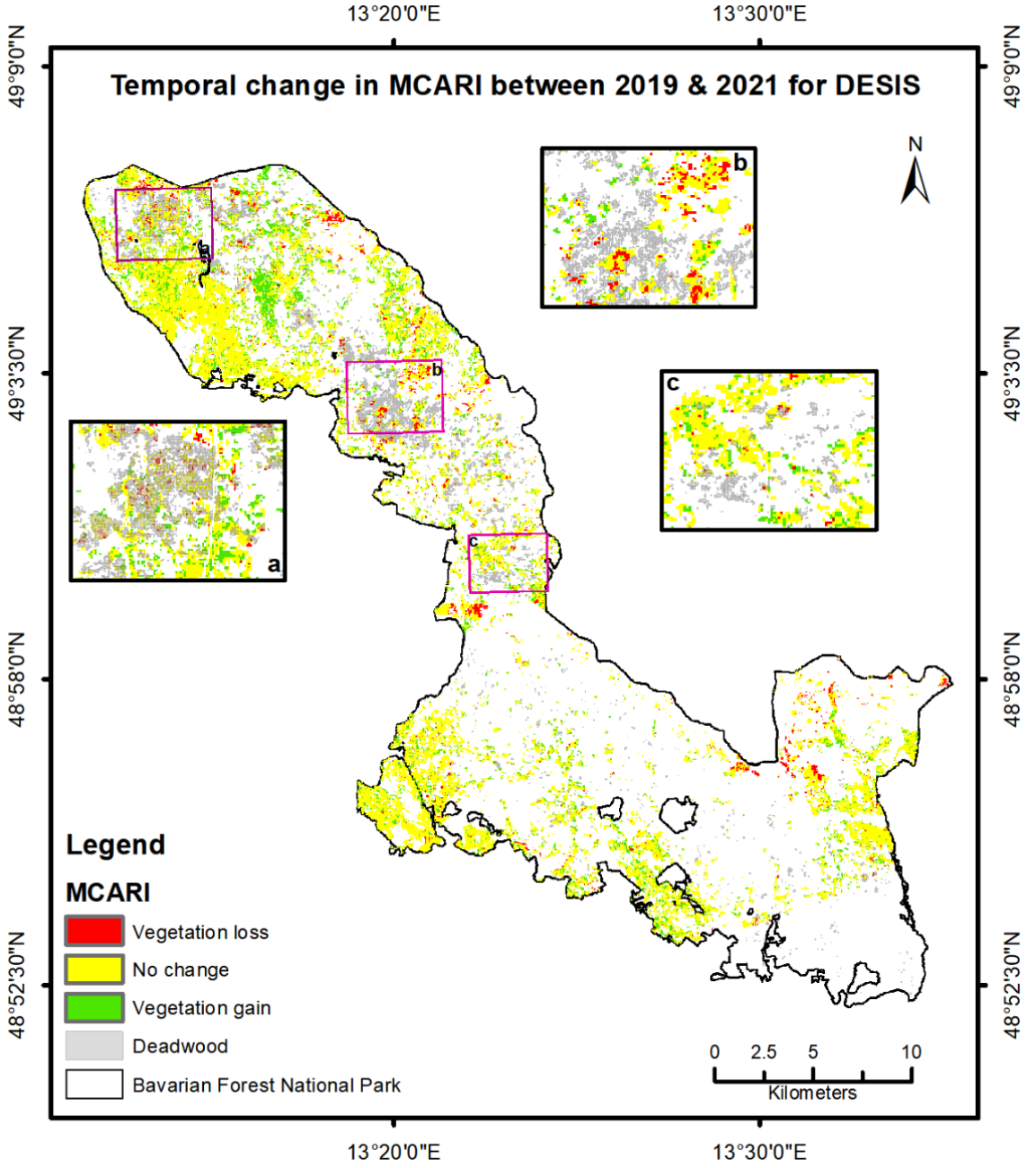
- Seasonal changes visible
- Similar trend of the value range between 2019 and 2020



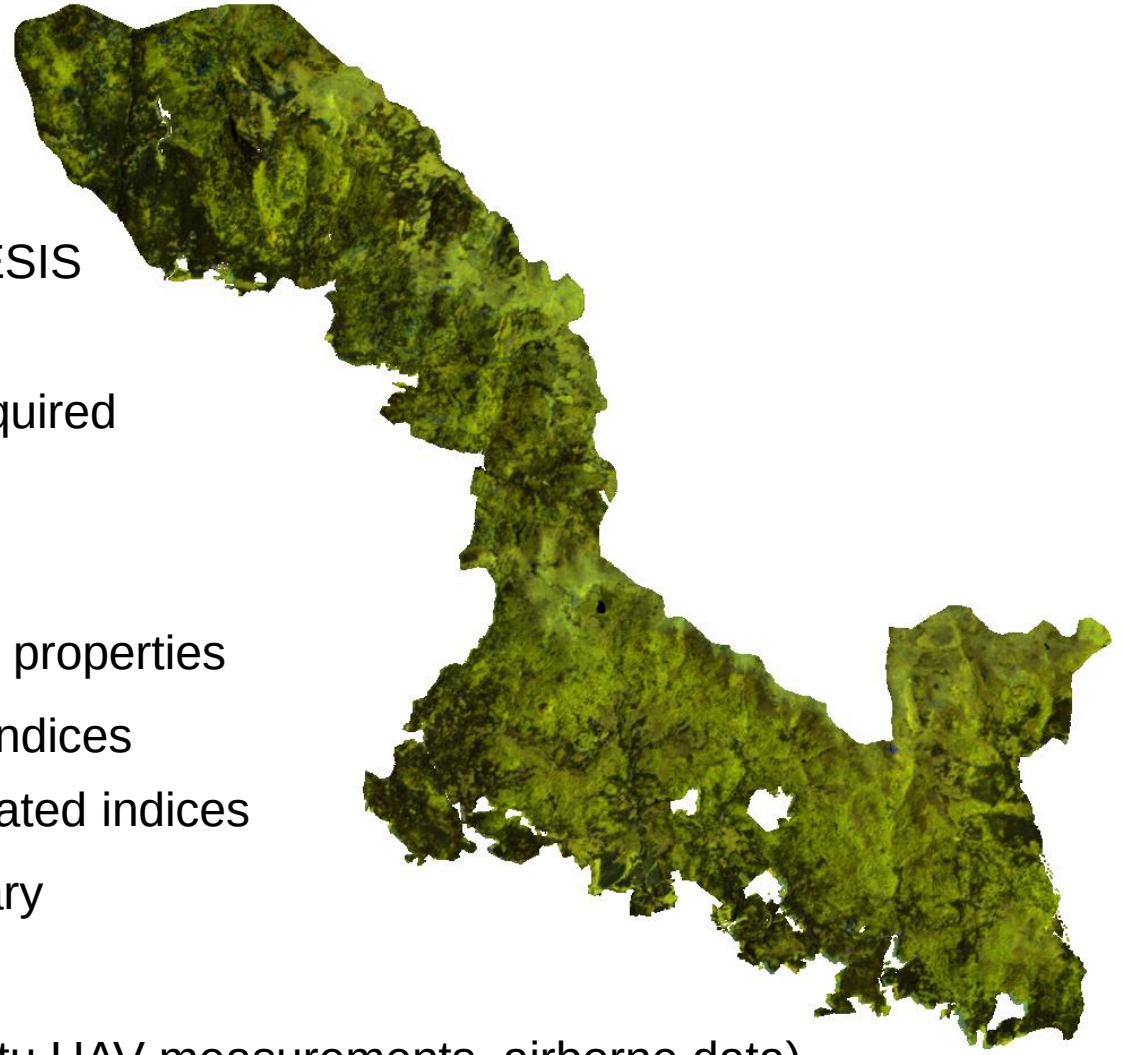


Temporal Changes in Vegetation: Example of DESIS Derived MCARI

- Modified Chlorophyll Absorption Ratio Index (MCARI) (Daughtry et al., 1999)
- Temporal changes between June 2019 and 2021
- Dynamics in correspondence with the mapped infested areas



Outlook and Conclusion



- Close examination of DESIS data show:
  - ✓ good agreement between Sentinel-2 time series and DESIS at BOA reflectance level
  - ✓ filtering of DESIS regarding view & solar geometry is required

→ High quality input data!!!

- Sentinel-2 data series used to show seasonal changes
  - ✓ Combined Vegetation Index (CVI) suitable to map forest properties
- DESIS data to display inter-annual changes of narrow-band indices
  - ✓ additional value of DESIS reg. chlorophyll & pigment-related indices
- Further comparison of different VI (-combinations) is necessary
- Continuously expand the time series with further data
- Include further supporting data sets (e.g. inventory data, in-situ UAV measurements, airborne data) for spectral analysis (BFNP excellent study site with many possible cooperations)

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